EXPERIMENT DATA MANAGEMENT PLAN (EDMP)
AMENDED EXPERIMENT DATA MANAGEMENT PLAN

EXPERIMENT NAME: BCAT-4 (Binary Colloid Alloy Test - 4)
MISSION TITLE: Space Station Increments 18, 19, and 20

(*FIELDS IN ITALICS ARE THOSE WHICH WILL BE USED FOR THE MASTER DIRECTORY DIF FILES*)

1.0 CONTACT INFORMATION

1.1 *Principal Investigators (PIs):*

[PIs for BCAT-4 samples 1-7]
Prof. David Weitz and Peter Lu
Harvard University
Department of Physics
Cambridge, MA 02138
Tel.: 617-496-2842 (Weitz)
E-mail: weitz@deas.harvard.edu (Weitz)
Tel.: 216-337-4981 (Lu)
E-mail: plu@fas.harvard.edu (Lu)
http://www.deas.harvard.edu/projects/weitzlab

[PIs for BCAT-4 samples 8-10]
Prof. Paul Chaikin and Dr. Andrew Hollingsworth
New York University (NYU)
Physics Department
4 Washington Place
New York, NY 10003
Tel.: 212-998-7694 (Chaikin)
Email: chaikin@physics.nyu.edu (Chaikin)
Tel.: 212-998-8460 (Hollingsworth)
Email: AndrewDH@nyu.edu (Hollingsworth)

1.2 Project Scientist:

Dr. William Meyer
NASA Glenn Research Center / NCSER
21000 Brookpark Road
Cleveland, OH 44135-3191

Tel.: 216-433-5011
Email: William.V.Meyer@nasa.gov

1.3 ***EDMP Author*** (Person responsible for validity of EDMP):
Dr. William Meyer, listed immediately above as the BCAT-4 Project Scientist

1.4 ***Archive Center Technical Contact***

Maura White
Lyndon B. Johnson Space Center
National Aeronautics and
Space Administration
Code IS45
2101 NASA Road 1
Houston, TX 77058
Tel.: 281-244-0322
Email: Maura.White-1@nasa.gov

2.0 EXPERIMENT DESCRIPTION

2.1 ***Experiment Name***
BCAT-4 (Binary Colloid Alloy Test - 4)

2.2 ***Mission*** (Mission name, Increments 18, 19, and 20, and launch date)

2.3 **Purpose**
Two frontiers of science are probed by the BCAT-4 experiment. They are: critical point behavior (when a gas and liquid become indistinguishable) and the crystallization of "glasses" in microgravity. This is done with two classes of colloidal samples: critical point colloid-polymer mixtures, and glassy mixtures of colloidal hard spheres at high volume fractions that crystallize when gravity is removed.

Understanding critical phenomena began as an important theoretical advance in physics during the last half century, but ground-based experiments have been limited by gravity. A gravitational field invariably causes a denser liquid phase to fall to the bottom of any container, preventing direct observation of the spatial structure of phase separation over the long term. In the absence of gravity, however, we can watch the boundary between separating phases and it does not look at all the same as on earth. The microgravity environment allows the phase boundary to assume its true thermodynamically-driven shape. Similarly, for concentrated suspensions of colloids that model the disorder to order transition, gravity causes sedimentation and jamming. In microgravity, beautiful crystals form in days to weeks using samples that remain glassy on earth. Samples 1-7 are mixtures of colloids and polymers near their liquid-gas critical point. Samples 8-10 consist of spherical colloidal particles with effective volume fractions that result in an amorphous or glassy phase in normal gravity. Earlier experiments (Colloidal Disorder-Order Transition, CDOT-1 & CDOT-2) have observed that gravity plays an overwhelmingly important role on the crystallization and glass-formation behavior with these spherical colloids, which are model atomic systems. We expect to observe how order arises from disorder using new systems of colloids in which we adjust the size polydispersity. For all the BCAT-4 samples, we will mix them with a mix magnet to completely randomize them, and then let them evolve into phase-separating “liquid-gas” mixtures (samples 1-7), or crystals (samples 8-10), whose time evolution we will monitor with a camera. Although simple in setup and execution, BCAT-4 has the unique ability to provide important data on experimental systems that cannot be accessed on earth, and will therefore, like its predecessor flight experiments, be able to contribute to our fundamental understanding of the thermodynamics and kinetics of colloids in particular, and materials in general.

BCAT-3 was the first experiment to use the size advantages of colloids, which can be used as model atoms, to systematically and precisely locate the critical point and characterize the behavior around it. BCAT-4 extends this work and adds important data points to the phase diagram. These larger particles are not only large enough to scatter light (which is visible to the camera, as well as the naked eye), but also large enough to slow down the dynamics to speeds that allow us to photograph the phase separation of samples over a period of weeks, assisted by apparatus already onboard the ISS.

Moreover, increased knowledge of some of the areas of this basic physical research may have future benefits in the application of the same physical processes on earth. Supercritical fluids (fluids that possess simultaneous properties of both a gas and a liquid) have numerous applications in a wide variety of fields. An example is supercritical carbon dioxide, which represents a solvent that can perform a wide variety of extraction and processing duties, an environmentally friendly solution replacing noxious or toxic solvents; It is used in dry cleaning, decaffeination of coffee beans, and extraction of delicate pharmacological molecules from plants for use in new drugs. The development and use of newer supercritical fluids is dependent on further understanding of the critical point of those fluids, which the BCAT experiments are providing. In addition, the specific dynamics of these colloid-polymer mixtures are of great economic importance to product stability: if phase separation occurs during the shelf-life of certain household products, then their value to the consumer evaporates. There is thus a significant commercial incentive, in a market worth billions of dollars annually, in coming to a better fundamental understanding of this particular mechanism, and BCAT-4 will certainly aid that process.

The so-called ‘model hard-sphere’ particle suspension experiments (samples 8–10) will extend our understanding of known self-assembly and thermodynamics processes in complex fluids. Clean observations of phase transitions in the microgravity environment will provide much needed insight about the interplay of polydispersity and sedimentation in affecting phase behavior. These effects are normally masked by gravity in experiments on earth. Traditional questions about the relative packing fractions, which crystallization phase is manifested, and the passing from one phase to the other, can be studied in these systems with exquisite resolution without the perturbing effects of sedimentation and jamming.

BCAT-4-CP: This portion of the experiment expects to fill in missing points in the phase diagram for these model critical systems. This should help us understand how phase separation operates. This translates into shelf-life, both on earth and on the way to Mars. BCAT-4-CP is akin to the vesicle polymer systems where the vesicle is expensive and the polymer cheap.

Procter & Gamble (P&G) wants to continue this work in BCAT-5 because they sell $1B dollars a year of fabric softener (e.g., Downy) and understanding this system will help them improve the product while telling them the minimum amount of visicle that is needed in the mixture.

BCAT-4-Poly: Understanding how order naturally arises out of disorder for concentrated systems when the restraining force of gravity is removed (in microgravity) is of fundamental importance. It will also impact the coming revolution in self-assembly with nanoparticles.

2.4 **Method**

This experiment combines a digital camera onboard the International Space Station with a book-size collection of ten samples cells. Each sample cell contains colloidal particles. The colloids in this science experiment are tiny plastic spheres that are about 100 times smaller than the diameter of a human hair. These small plastic balls are coated (with a layer of PHSA) to get rid of electrical interactions and suspended in an index matching fluid that allows them to look transparent. These colloidal particles are small enough to behave like models of atoms, but big enough to interact with visible light; and because of their size they move slowly enough that they can be used to model and directly observe all sorts of phenomena. While the colloids in the ten samples in the BCAT-4 experiment are made from the same ingredients, each recipe has different proportions, and the first seven samples contain different amounts of polymer to create a depletion attraction. This enables us to probe Nature's natural organizing tendencies when the effects of gravity are removed; that is, when the effects of sedimentation (settling) and convection (stirring) have been removed. Each sample is homogenized by passing a magnetic stir-bar up and down through the sample. Then the samples are repeatedly photographed as they come to equilibrium.

For BCAT-4-CP Critical Point Samples (1-7): Crew members will homogenize the samples and photograph one sample at a time, to capture the rate of phase separation in the samples using EarthKAM automated photography over a period of 2 – 3 weeks per sample. Images will be downlinked to allow scientists to provide immediate feedback to the astronauts.

For the BCAT-4-Poly Colloidal Crystal Samples (8-10): Crew members will homogenize the samples and will look for crystals at various lighting angles. The crystals will be manually photographed and downlinked for immediate feedback to the astronauts.

After photography the samples are stowed and left undisturbed to allow for continued growth of the colloidal structure for up to 6 months.

2.5 ***Facility Used***

International Space Station Bench Top Experiment that uses either an overhead rail mount or the maintenance work area (MWA).

2.6 ***General Experiment Summary***

Objectives:

BCAT-4 is performed in a microgravity environment to remove the effects of sedimentation, convection, and jamming, enabling these experiment, which cannot be done on earth.

BCAT-4-CP: When the masking effects of gravity are removed, the BCAT-3 model critical point samples separated into two phases at a surprising rate. The BCAT-4 experiments add needed data points to the experimentally determined phase diagram. This data is essential for modeling and understanding the origin of this behavior.

BCAT-4-Poly: It is now believed that the crystallization of concentrated hard spheres for both monodisperse systems (with and without nanodirt) and polydisperse systems is very different in microgravity. Microgravity should enable crystallization of systems that remain glassy (disordered) on earth, allowing scientists to better understand how order arises out of disorder.

Experimental Method:
Astronauts will setup BCAT-4 on the International Space Station (ISS) overhead rail or on the MWA and then homogenize each sample and take photographs of each sample: automatically timed photographs will than be taken using a Kodak 760 camera and an EarthKAM script to document phase separation or crystal formation in the ten colloidal samples.

2.7 **Summary of Results and Data** (A short summary of experiment results to be included in the amended EDMP; can be taken verbatim from another source, e.g. Executive Summary of the Investigator's Final Report.)

The BCAT-4 experiment will be delivered to the International Space Station (ISS) in December 2008 and began running in May of 2009.

2.8 **Keywords** (Discipline, Subdiscipline, Parameter Group and Parameter are terms used in the Master Directory to aid in a user's search for data sets. There is a standard list of keywords provided by MSAD to use to fill out these four sections; they are located at the end of this EDMP – [not in this draft].)

2.8.1 ***Discipline***
Microgravity

2.8.2 ***Subdiscipline***
Fluids

2.8.3 ***Parameter Group***
Soft-Condensed Matter

2.8.4 ***Parameter***
Critical Fluids, Surface Crystals, Binary Alloys

2.8.5 ***General Keywords*** (Any keywords that do not fit within first four levels of keywords. Since there is no standard list for 'General Keywords', this section should contain all the specialized terms that apply to the experiment (e.g. Gallium Arsenide).

3.0 PROCESSING AND ANALYSIS DESCRIPTION

3.1 **Measurement Techniques** (Provides a description of instrumentation used, types of measurements taken, etc.)

Digital photographs of BCAT-4 samples will be taken by astronauts for ISS Increments 18, 19, and 20. EarthKAM will assist astronauts photograph sample kinetics and evolution as a function of time.

3.2 **Analysis Techniques Performed** (on-orbit, in the operations control center, and post flight by the PI and team.)

Digital image processing is used to remove specs of lint and the like captured by the camera. Image enhancement techniques are used to improve image contrast and quality. Software Fourier transforms of the images are used to determine correlation lengths as a function of time.

4.0 ARCHIVING AND ACCESSIBILITY

4.1 ***Data Archive Center*** (The pre-flight EDMP should state the MSAD Archive Center assumed to receive the data after flight, if there are more than one expected location for the data, please describe; the amended EDMP will state the location(s) of the data inventory.)

JSC Imaging Working Group.

4.2 **Inventory of Data to be Archived** (The pre-flight EDMP describes data types and quantities expected to result from the investigation; the amended EDMP provides data types, media, formats, quality, quantity, location, special storage requirements, etc. for all archived data.)

BCAT-4 digital photos and camera sound files from ISS Increments 18, 19, and 20.

4.2.1 **Video Tape** (Quantity, tape format, tape numbers, supply additional page if needed.)

No video tape was used for recording flight data for this experiment.

4.2.2 **Film** (Quantity, film format (16 mm, 35 mm, etc.), film numbers, etc.)

No film was used for recording flight data for this experiment.

4.2.3 **Digital Data** (Flight digital data, documentation files, drawing files, etc. A readme file should state whether the data is raw or processed, data formats, conversions, etc.)

Raw file format flight data for the BCAT-4 experiment in the form of Kodak *.DCR and *.WAV (wave) files should be archived. These files will be NASA numbered and added to the BCAT-3 flight data photos and wave files from Increments 8 – 17, and later, if they come to exist. The typical format for these photos will be ISS019E#####_NR, where 019E stands for Expedition-19, ##### is the photo number, and _NR indicates that it is not to be released until its delayed release status expires or the Primary Point of Contact (Monica Hoffmann) requests this information be released.

These files should be run through the Mathematica program entitled "Import BCAT-3 data files 012.nb", which was written by W. Meyer (or an equivalent program). This program will parse the data into a Microsoft eXcel spreadsheet that lists all the data files and the settings on the camera for each photograph. The spreadsheet data includes "File Name, File Date, File Time, Sample #, Postmix time, Wave File Created [yes or no], Shutter, Aperture, ISO Speed, Max Aperature, Min Aperature, Focal Length, Exposure Mode, Meter Mode, Drive Mode, Focus Mode, Focus Point, Flash Mode, Compensation, Flash Compensation, Self Timer Time, and Temperature", with the values for "Sample #, Postmix time, and Temperature" being added by hand. The Mathematica program referenced above is attached to this document. This BCAT-4 spreadsheet along with the temperature data from the TREK computer will be sent out to the BCAT-4 Principal Investigators (PIs), if possible, with the data that is being sent on a CD ROM. A final summary spreadsheet and the raw temperature data summary from the TREK computer will be burned to CD ROMS and sent out to the NASA PIs; this summary will include data from Space Station Increment numbers 18, 19, and 20.

4.2.4 **Samples** (Unused/used samples, memos, photographs (C-numbered.))
BCAT-4 samples will be returned to the PIs once they've bee returned to Earth. The digital photo files will be numbered and stored with the JSC Imaging Working Group.

4.2.5 **Other**

4.2.6 ***Publications/Reports/etc***
Interim reports for BCAT-3 have been submitted and archived by Professor Weitz and Peter Lu (Harvard). They are available from the Project Manager (Ronald Sicker) and the Project Scientist (William Meyer) at NASA GRC.

4.2.7 **Related Ground Based Experiment Data**
Related ground-based experiment data is held at Harvard (David Weitz and Peter Lu) and NYU (Paul Chaikin and Andrew Hollingsworth), not to be placed in NASA archive.

4.2.8 **Data Not Archived** (If a decision is made not to archive specific data, give justification and description of that data.)

4.3 **Data Accessibility and Availability** (The pre-flight EDMP should describe the delivery schedules for the data to the archives and any expected accessibility restrictions; the amended EDMP should describe any unique accessibility or availability issues.)
The BCAT-4 data has a deferred release date of 24 months from the time the mission is concluded, which would be the end of ISS Increment-20.

4.4 **Policies for Proprietary Data** (State any proprietary policy agreements that will impact the availability of the data to the science community.)
The BCAT-4 PIs will have exclusive rights to access and publish this data for a period of two years and then it goes into the public domain. Of course, the BCAT-4 PIs have the right to release their own portion of the BCAT-4 data to whomever they choose at any time by providing a written note to this effect. This note would be submitted to the Primary Point of Contact, Ronald Sicker, the BCAT-4 Project Manager at NASA GRC; or to the Imaging Working Group, Attn: Jason Leblanc or Jason Levy.

Revision Date: 24 January 2008 (by Dr. W. Meyer, BCAT-3/4/5 Project Scientist)